USING FAILURE RATE DATA

Mil-HDBK-217: Electronic Systems

(07)

FAILURE RATE

- **The number of failures of an item within the population per unit of operation (time, cycles, miles, runs, etc.)**

ELECTRONIC SYSTEM RELIABILITY - WHY IMPORTANT?

- PROBLEMS
  - Electronic systems involves the utilization of very large numbers of components which are very similar.
  - The designer has little control over their production and manufacture but must specify catalogue items.
  - The designer has little control over device reliability.
  - Control of the production process is a major determinant of reliability.
  - It is difficult to test for electronic component defects that do not immediately affect performance.
- SOLUTION: Very close attention must be paid to electronics part reliability. The design must involve a reliability team.

OBJECTIVES:

Be able to answer (or know/perform):

- **What are the main causes of electronic equipment failure?**
- **How can each type of failure be prevented?**
- **What are the categories (broad) of electronic parts rating?**
- **What are the benefits of Mil-HDBK-217x?**
- **Do a reliability prediction using the parts stress analysis and parts count method.**
- **What are the limitations of Mil-HDBK-217x?**
- **What are other sources of failure rate data and how should they be used?**

OUTLINE

- DEFINITIONS
- CAUSES OF ELECTRONIC COMPONENT FAILURE
- PREDICTION METHODS-TEST
- Mil-HDBK-217 PREDICTION METHODS-CALCULATIONS
  - PARTS STRESS ANALYSIS PREDICTIONS
  - PARTS COUNT RELIABILITY METHOD
  - LIMITATIONS
- ADDITIONAL INFORMATION
  - Other Failure Rate Data Sources
  - Arrhenius Model

DEFINITIONS

- **OPERATING STRESS**
  - **The actual stress (or load) applied during operation of the part (e.g. voltage for capacitor, dissipated power for resistors)**
- **RATED STRESS**
  - **The manufacturers rating for the part.**
- **STRESS RATIO**
  - **Ratio of operating stress to rated stress.**
- **PART GRADES**
  - **Grade 1, 2 etc. designates high quality standard parts.**
  - **JAN, Industrial and Commercial Grades designations for other parts that can be used.**

BACKGROUND

- Reliability engineering and management grew up largely in response to the problems of electronic equipment reliability.
- Many reliability techniques have been developed from electronics applications.

CAUSES OF ELECTRONIC COMPONENT FAILURES

Electronic Failures =

f (design, mfg.process, quality type, temperature, electrical load, vibration, chemical, stresses)

PROCESS CAUSES OF ELECTRONIC COMPONENT FAILURES

DEFECTIVE BONDS

- **Affected by voltage applied across it.**
- **Ambient temperature around the device.**
- **Mechanical loading caused by vibration.**
- **Broken or lifted bond wire from poor bonding / corrosion.**

DIE RELATED

- **Electromigration from ionic diffusion of conductor matl.**
- **Minor undetectable defects affected by temp. & voltage.**
- **Voltage overstressed caused by electrostatic discharge or arcing.**
- **Internal short-circuits caused by voids in dielectric layer**
- **Incorrect output can result from improper materials.**

PROCESS CAUSES OF ELECTRONIC COMPONENT FAILURES (con't)

- **Parameter drift.**
- **Short circuits due to solder defects, balls, splash.**
- **Damage during assembly (heat, mechanical load)**
- **Wave soldering techniques which is not carefully controlled; results difficult to inspect.**
- **Contamination during fabrication of ICs or board.**
- **Non-hermetic packaging leading to corrosion.**

QUALITY RATING (& Testing) EFFECTS ON ELECTRONIC COMPONENT FAILURES

- **Screening acceptance criteria must be tight enough to eliminate drift in tolerance over time as a failure cause.**
- **US-MIL-STD-883, Test Methods and Procedures for Microelectronics (gives three basic screening levels of A, B, C).**
- **Device quality depends upon the control exercised over the production process. The standards that exist to control specifications and manufacturing processes and approvals of the production lines are MIL-M-38510.**

QUALITY RATING (& Testing) EFFECTS ON ELECTRONIC COMPONENT FAILURES (con't)

- Testing-Types of Electronic Parts Ratings for Transistors and diodes:
- JAN TXV (100% pre-encapsulation inspect, burn-in)
- JAN TX (100% burn-in)
- JAN JAN, BS 9300
- Com. Com., hermetic, glass seal
- Com. Com., plastic seal

QUALITY RATING (& Testing) EFFECTS ON ELECTRONIC COMPONENT FAILURES (con't)

- **Testing-Types of Electronic Parts Ratings: Microcircuit devices**

• A	MIL-M-38510, class S
• B,B-0	MIL-M-38510, class B
• B-1	MIL-STD-883, method 5004,Class B
• B-2	Vendor eqv. of B-1
• C	MIL-M-38510, class C
• C-1	Vendor eqv. of C
• D	Commercial, hermetic seal
• D-1	Commercial, plastic seal

CAUSES OF ELECTRONIC COMPONENT FAILURES

Temperature Related

- Semiconductor devices means pass of higher current.
- Power dissipation per unit volume in ICs is increasing resulting in a thermal management problem.
- Increased temperature may accelerate chemical breakdown of components.
- Increased temp. changes resistance of components.

OTHER CAUSES OF ELECTRONIC COMPONENT FAILURES (con't)

Electrical Load

- **Higher that anticipated voltage or current loads can cause arcing, and other damage.**

Vibration

- **Shock and vibration can cause fatigue damage to even properly made components.**

Chemical

- **Contaminants introduced in the manufacturing process may eventually degrade an IC or other device.**
- **Environmental contaminants (moisture, etc) may promote chemical attacks on components.**

Mil-HDBK-217 PREDICTION METHODS
PARTS STRESS ANALYSIS PREDICTIONS

- This method is applicable when most of the design is completed and a detailed parts list including parts stresses is available.
- This model takes into account part quality, use environment, the base failure rate (which includes electrical and temperature stresses)

Mil-HDBK-217 PREDICTION METHODS
PARTS STRESS ANALYSIS (con't)

$$\lambda_p = \lambda_b \pi_T \pi_A \pi_R \pi_s \pi_c \pi_Q \pi_E$$ **(Failures/10^6 Hour)**

where:

λ_p **= parts failure rate (Failures/10^6 Hours)**

λ_b **= base failure rate (often with electrical, temp. stress)**

π_T **= Temperature Factor (dimensionless typical 1 - 150)**

π_A **= Applications Factor (dimensionless, typical 1- 5)**

π_R **= Power Rating Factor (dimensionless, typical 0.5-1.0)**

Mil-HDBK-217 PREDICTION METHODS
PARTS STRESS ANALYSIS (con't)

π_s = Voltage Stress Factor (dimensionless, typical 0.1-1.0)

π_c = Construction Factor (dimensionless, typical 1 - 5)

π_Q = Quality Factor (dimensionless, typically 0.7 to 8.0)

π_E = Environmental Factor (dimensionless, typical 1 - 450)

Each devices uses some or all of these factors. Other factors are also used.

P7-1+

Mil-HDBK-217 PREDICTION METHODS
COMBINING RESULTS

- **The general procedure for determining board level failure rate is to:**
- **Sum individually calculated failure rates for each component.**
- **This summation is then added to a failure rate for the circuit board (which includes the effects of soldering parts to it).**
- **Then effects of connecting circuit boards together is accounted for by adding in a failure rate for each connector.**

Mil-HDBK-217 PREDICTION METHODS
Non-operating Failures

- **Parts continue to fail even when not in use. In general electronic parts fail less frequently when not operating because failures are related to operating stress. But other components tend to degrade even when not in use. Example:**
  - **Hydraulic parts fail because organic rubber seals out gas and cross link when exposed to heat and ultraviolet light.**
  - **Solid rocket engines undergo chemical degradation and can develop cracks.**
- $R_s = R_{operating} R_{non\ operating}$

Mil-HDBK-217 PREDICTION METHODS
Parts Count Reliability Method

- Used early in the design or when detailed data is not available.
- Uses Generic Part Type, a Quality Factor and Environmental Factor.
- information needed:
- (1) generic part types (including complexity for microcircuits) and quantities,
- (2) part quality levels, and
- (3) equipment environment.

Mil-HDBK-217 PREDICTION METHODS
Parts Count Reliability Method

$$\lambda_{EQUIP} = \sum_{i=1}^{i=n} N_i(\lambda_g \pi_Q)_i$$

λ_{EQUIP} = Total equipment failure rate (Failures/10^6 hrs.)

λ_g = Generic failure rate for i^{th} generic part.

π_Q = Quality factor for the i^{th} generic part.

N_i = Quantity of the i^{th} generic part.

n = Number of different generic part categories in the equipment.

Mil-HDBK-217 PREDICTION METHODS

LIMITATIONS

- **RELIABILITY PREDICTION MUST BE USED INTELLIGENTLY, WITH DUE CONSIDERATIONS TO ITS LIMITATIONS**
- **FAILURE RATE MODELS ARE POINT ESTIMATED WHICH ARE BASED ON AVAILABLE DATA**
  - **THEY ARE VALID FOR THE CONDITIONS UNDER WHICH DATA OBTAINED AND DEVICES COVERED.**
  - **MODELS ARE INHERENTLY EMPIRICAL**

CONCLUSION--USING PARTS FAILURE RATE DATA

- PARTS STRESS & PARTS COUNTS ANALYSIS GIVES FIRST ORDER APPROXIMATION.
- USED FOR COMPARISON PURPOSES.
- USED TO HELP WITH RELIABILITY ALLOCATION.
- NEEDS TO BE VERIFIED WITH TEST DATA.

Additional Information

PARTS FAILURE RATE DATA SOURCES

Government Industry Data Exchange Program (GIDEP)

- **This is a database run by the Navy including engineering, failure rate, metrology, failure experience, diminishing resources.**
- **Also provides for Alerts and Problem Advisories.**

H(opt)

Problem Reporting and Corrective Action (PRACA)

- **NASA LeRC ... Problem reporting system (typical).**

Nonelectric Parts Reliability Data, 199x

- Reliability Analysis Center, Rome, NY.
- Table of failure rates for various types of non-electronic parts.

FAILURE RATE MODELS

ARRHENIUS MODEL

- **ACCORDING TO THE ARRHENIUS MODEL, THE RATE OF A CHEMICAL REACTION OR FAILURE MECHANISM (A PROCESS) IS GIVEN BY THE EMPIRICAL FORMULA:**

$$\lambda_b = ce^{(-a/kT)}$$

ARRHENIUS MODEL

Where:

λ_b **= process rate (base hazard rate)**

a **= activation energy (function of reaction)**

k **= Boltzman's constant**

= (1.38x10^{-23} JK^{-1}) or (86.3X10^{-6} eV K^{-1})

T **= Ambient Temperature (deg. Kelvin).**

c **= normalization constant**

COMPONENT LIFE

- Usually the life of a component, L, is assumed to be inversely proportional to the rate of the failure process giving:

$$L = c_2 e^{(a/kT)}$$

COMPONENT LIFE (con't)

- IF T_u and L_u denote the temperature and life during normal use and T_a and L_a indicate the temperature and life during actual operation then we have:

$$L_a/L_u=exp\{a/k[(1/T_a)-(1/T_u)]\}$$

END

F

PROB 7-1 PARTS STRESS

400 VDC RATED CAPACITOR TYPE CQ09A1KE153K3
SPACE FLIGHT ENVIRONMENT
55 DEG C COMPONENT AMBIENT TEMPERATURE
200 VOLT DC APPLIED WITH 50 v-RMS @ 60Hz.
BEING PROCURED IN FULL ACCORDANCE WITH APPLICABLE SPECS.
(BASED ON MIL-217 EXAMPLE P.10-32)

NOTATIONS:
CQ = TYPE DESIGNATION INDICATING SPECIFICATION IS MIL-C-19978
AND IT IS NON-ESTABLISHED RELIABILITY QUALITY LEVEL.
K (1ST) = CHARACTERISTIC K
E = 400 VDC RATING
CAPACITANCE IN PICOFARADS = 15 x 10^3 PICO = 1 X 10^-12; MICRO = 1 X 10^-6

S = (DC Volts Applied) + $2^{(1/2)}$ x (ACV Applied)/ (DC Volts rated) = Stress Level

S = (______________) + $2^{(1/2)}$ x (____________) / (___________) = __________

λ_b = 0.0005 [$(S/0.4)^5$ + 1] x exp [2.5 [(T+273) / 398]^{18}] = __________

π_{CV} = 1.3 C $^{0.077}$ = 1.3 x (_______) $^{0.077}$ = __________

(Use table "Capacitance Factors" Equation (0.015 micro farads).

π_q = _________ **(Use table "Quality Factor" for MIL-C-19978, Non-Est Rel.)**

π_E = _________ **(Use table " Environmental Factors)**

λ_p = λ_b x π_{CV} x π_Q x π_E = ________ x ________ x ________ x ________ x ________

λ_p = ________ **failures / 10^6 hours**